CHIPSat – A Node on the Internet

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CHIPSat Background

Cosmic Hot Interstellar Plasma Spectrometer

- **First NASA University Explorer (UNEX) project (~$13-15M)**
  - P.I., Mark Hurwitz, Space Sciences Laboratory (SSL), Berkeley, CA

- **SpaceDev selected to design mission, provide bus, integrate, and operate for 1-year**
  - Single-string, COTS, and modular industry standards hardware/software approach
  - Fixed solar arrays on all sides for power positive in all modes
  - 300 MIPS PowerPC750-based single board computer with VxWorks RTOS
  - ***End-toEnd Link: IP-based software and communications architecture***

- TCP/IP is a natural choice for the transport of complex data streams
  - Fundamental requirement of all satellite systems is the communication between devices contained within a satellite and the ground station
    - Using TCP/IP reduces this task to resource integration
- VxWorks (and other commercial RTOS's) are proven flight system resources
  - The TCP/IP protocol stack, socket, message queue, and tasking are already available as system resources
- HDLC & Bi-phase (or NRZI) provides data link layer for interface for transceivers

CHIPSat is the first NASA mission to use end-to-end IP-based communications

How It Stacks Up

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100BASE-T or Satellite RF

Ethernet or HDLC

IP

TCP   **UDP**

Telnet   FTP   Custom Sockets   SNTP

Downlink:
FTP - Stored Science Data
FTP - Stored H/Keeping Data

Uplink:
FTP – Stored timed-file commands

Downlink:
UDP - Real-Time Science Data
UDP - Real-Time H/Keeping Data

Uplink:
UDP - All real-time commanding

Trade-Offs

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- ## Packet-dropping
  - *TCP*: 100% reliability via transparent re-transmit without use of any application s/w
  - *UDP*: CHIPSat flight s/w command protocol uses operator-verified echoes to provide positive acknowledgement
- ## Bandwidth
  - 3-6% framing overhead with TCP& UDP
- ## Data-Latency
  - Our research and testing (Poway / Berkeley / Adelaide) to date indicates that for LEO missions, latency is not increased significantly by the space segment
  - Challenges associated with deep-space and straight IP
    - TCP will not work due to longer latency
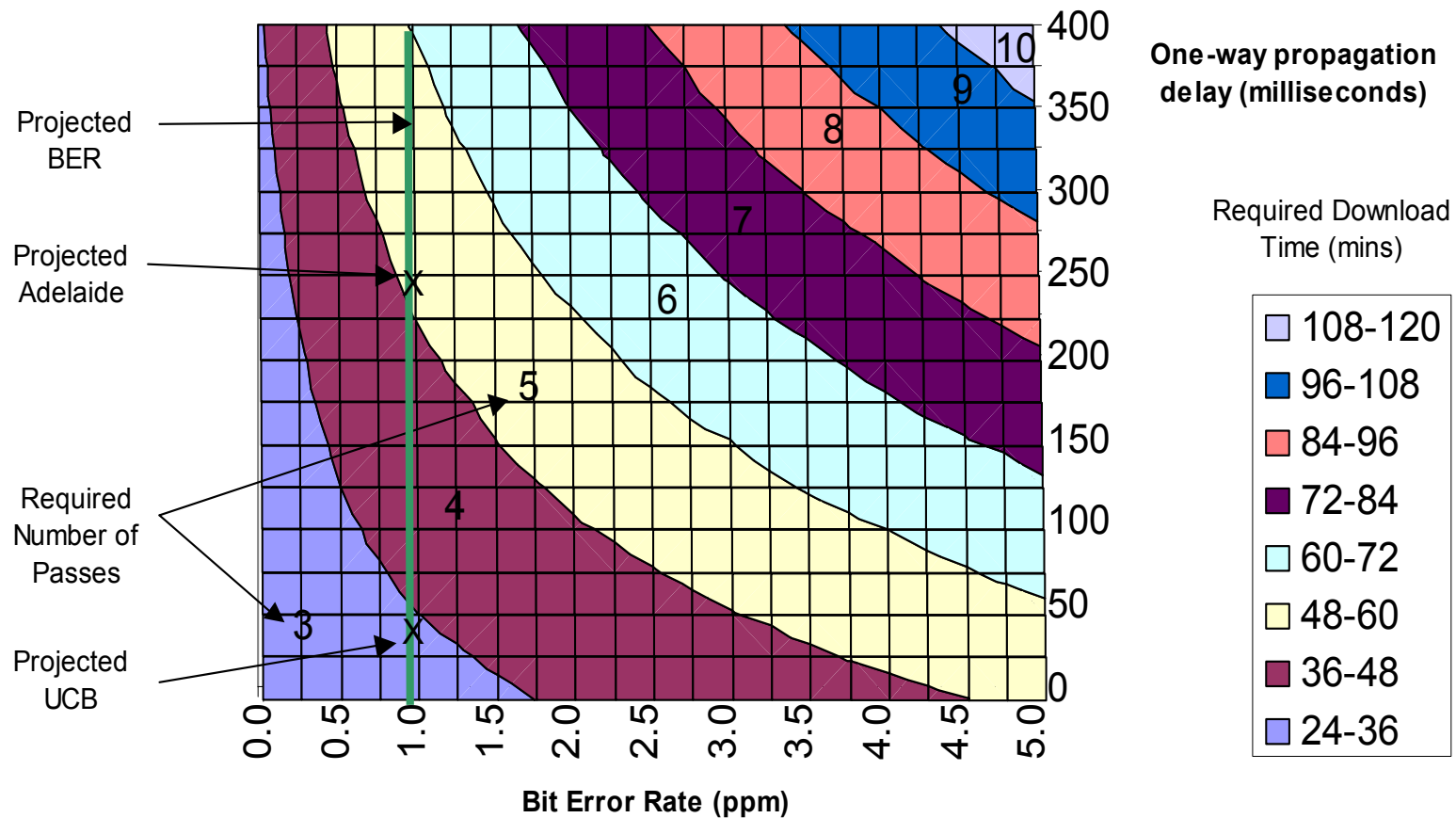   - UDP would require some customization for efficient communication

TCP Analysis Results
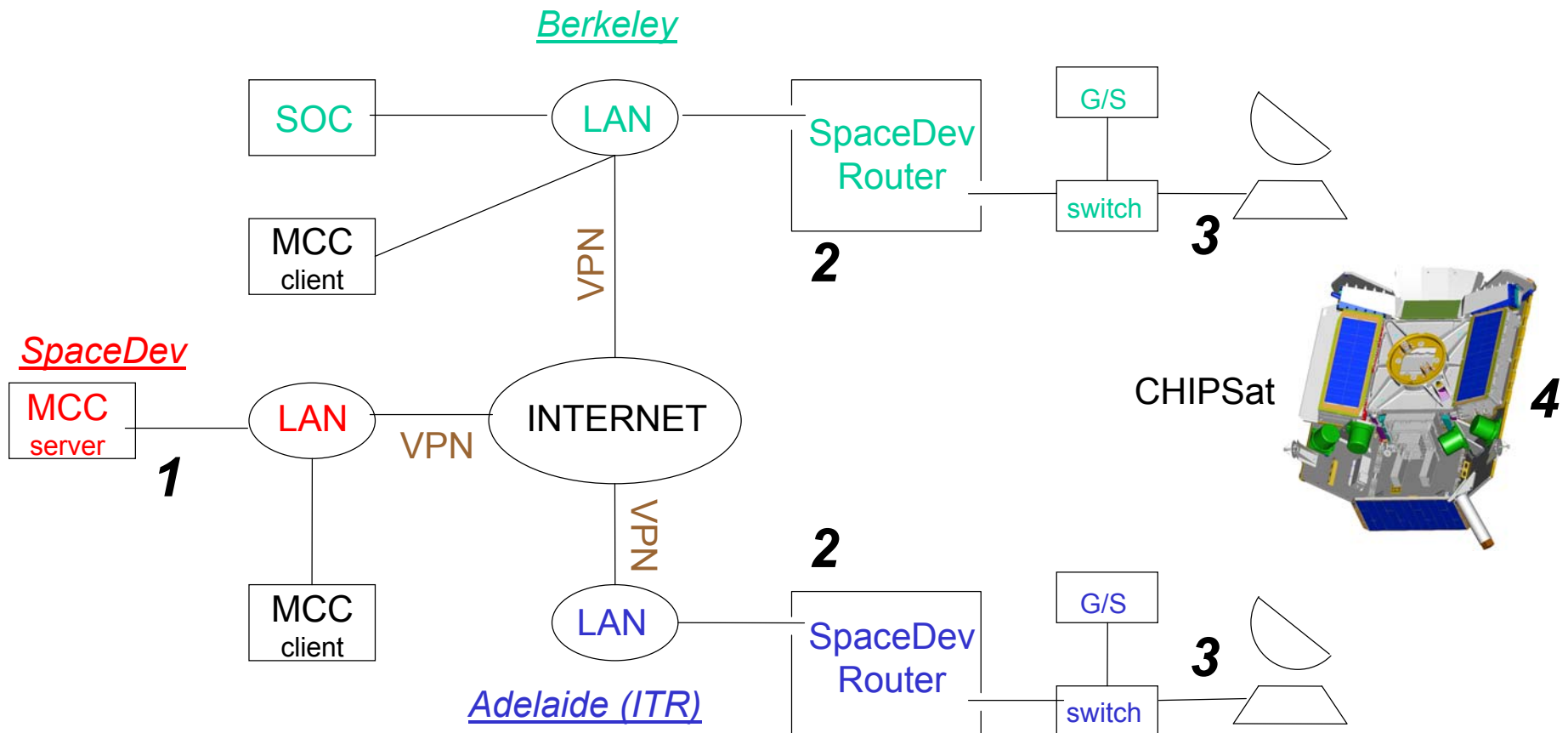
CHIPS

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One-way propagation delay (milliseconds)

Required Download Time (mins)

- 108-120
- 96-108
- 84-96
- 72-84
- 60-72
- 48-60
- 36-48
- 24-36

Projected BER

Projected Adelaide

Required Number of Passes

Projected UCB

Bit Error Rate (ppm)

Overview of CHIPSat Data Flow

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Day-in-the-Life of a CHIPSat Packet

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1. Command issued by an MCC client as TCP/IP packet to SpaceDev MCC server; SpaceDev MCC Server validates and forwards on as UDP/IP packet

2. Packets are routed to appropriate SpaceDev router through the VPN; Router validates and then outputs packets within an HDLC frame
   - SpaceDev router bridges two interfaces: HDLC & Ethernet

3. HDLC frame enabled by switchbox to be modulated onto an S-Band carrier; transmitted by ground station
   - SpaceDev switchbox provides digital serial port to analog RF

4. CHIPSat receiver demodulates and passes HDLC frame on to CHIPSat flight computer; HDLC serial port strips off each frame, validates, and forwards as UPD/IP packet

Secure Networking

- VPN utilizes multiple Internet Protocol Security (IPSec) tunnels
  - Firewall used in conjunction with VPN
  - Provides Authentication and Encryption
  - As used in corporate transactions
  - Only pre-authorized computers have access to s/c resources
- MCC Computers are password protected
- Written details of architecture secure
- Implementation can be at any site with a fixed IP-address, PC and Windows OS
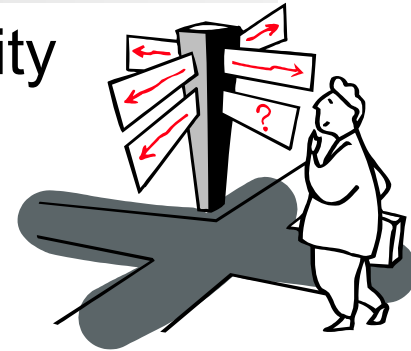
Data Volume Overview

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DOWNLINK VOLUME

Factor	BGS	ITR	Units
Min Time b/w passes	13.00	20.00	mins
Min Pass Duration	180.00	180.00	seconds
FTP Handshake Time	20	20	seconds
FTP Efficiency	0.9	0.9	ratio
Downlink datarate	115200	38400	bps
Data Volume	**16.6**	**4.2**	MB / day

GENERATED VOLUME

Source	Quantity	Units
S/C housekeeping	2.2	MB / day
CHIPS total	14.3	MB / day
Total Volume	**16.5**	MB / day

Data Volume Margin

Total Produced	16.5	MB / day
Total Downlink	20.8	MB / day
Margin	**25.9**	%

ASSUMPTIONS

1) no pass-specific S/C pointing maneuvers
2) actual BGS mask; 10-degree mask at ITR
3) Fedsat in sun-sync orbit at 600 km altitude
4) 30W ITR uplink power; 10W BGS uplink power
5) Bi-phase data encoding
6) Local CHIPSat Router PC FTP sessions with store-and-forward data delivery to the MCC

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- >1000 passes, 154 days

- ~14 MB average download per day

- Data Latency
  - ~95% of latency occurs on the terrestrial portion for Wallops and ITR
  - ~80% for BGS due to less latency for short CA hop

- Internet outages
  - 5 occurrences during a pass since launch
    - Outage averages <5 minutes and is sometimes intermittent
  - Store and forward capability with Router allows for retransmission immediately after Internet is back on-line

- Continued use of TCP/UDP/IP for end-to-end LEO microsat communications
  - As a bus comm protocol, TCP/UDP/IP reduces software development cost and leverages the latest OS and embedded software advancements
  - Other payload protocols (I.e, SGLS, STDN, etc.) can be encapsulated within TCP/UDP/IP datagrams if necessary

- Improve bandwidth efficiency
  - IP is bandwidth inefficient; SpaceDev is investigating methods of improvement in software with its router and microsat operating system

- Extension of a LAN to a WAN
  - SpaceDev will be working on intersatellite comm using TCP/UDP/IP

SpaceDev Contacts

Cosmic Hot Interstellar Plasma Spectrometer

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